BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 07053

SUBJECT: Flight Test of the LM Landing Point Designator - Case 310

DATE: July 17, 1969

FROM: A. C. Merritt

ABSTRACT

Flight test of the Landing Point Designator (LPD) on Mission H-1 should involve realtime selection of a debris-free landing point approximately 6° to the left and 0.5° uprange of the unredesignated target point (at 5000 feet altitude), and tracking of this selected point until the time of manual takeover. The flight test will determine the effect of LPD operation on crew task loading and the effect of the LPD attitude and trajectory response on the initial conditions at manual takeover.

Prior to final approval of the LPD flight test, supporting data should be prepared in the following areas.

1) Landing Radar roll sensitivity

2) Onboard chart of allowable number of redesignation pulses vs. altitude or velocity

3) Identification of scientific targets over the entire footprint

4) Simulations of the effect of LPD attitude response on manual takeover

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MEMORANDUM FOR FILE

INTRODUCTION

The Apollo Flight Mission Assignments requirement to initiate development of a point landing capability on Mission H-1 can be met by improving the navigation accuracy at powered descent initiation and by flight testing the LM Landing Point Designator (LPD). On the lunar exploration missions that do not include mobility aids, there will be a strong requirement to use the LPD to partially correct for navigation and guidance errors. Without targeting corrections, the LM is likely to land too far from the pre-planned site to permit achievement of the intended scientific return of the mission. It is therefore important to verify that the LPD can be successfully used in flight to retarget the LM landing point to the desired landing site.

This memorandum will discuss the LPD flight test possibilities defined by the current delta-V budget and attitude constraints. Section 1 includes a description of the LPD system and the current redesignation capability. Flight test limits are then established within the defined capability. Section 2 discusses crew procedures during the LM descent Approach Phase, in order to indicate the expected impact of LPD redesignation on crew task loading. Section 3 concludes with a proposed flight test that meets the requirement to develop a point landing capability without an excessive delta-V penalty or additional crew hazard.

SECTION 1: LANDING POINT DESIGNATOR DESCRIPTION

The Landing Point Designator (LPD) is a manually-commanded control system comprised of the equipment shown in Figure 1. The scale on the LM left-hand window is used to obtain an indication of the error between the desired target point (desired site) and the current target point (current site). The R1 DSKY (Display and Keyboard) register simultaneously displays two numbers that describe the LM position relative to the current site. The two digits displayed on the left of the R1

(NASA-CR-106565) FLIGHT TEST OF THE LM LANDING POINT DESIGNATOR (Bellcomm, Inc.) 25 p

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register give the number of seconds to go to the current site, up to 99 seconds.* The two digits displayed on the right of the R1 register give the approximate window elevation angle of the current site. The LM Guidance Computer (LGC) automatically yaws the LM in order to zero the window azimuth angle of the current site. (The LM attitude rotation conventions are shown in Figure 2.)

By identifying the desired site and comparing its window coordinates with the window coordinates of the current site, the commander can decide what corrections should be made in order to target for the desired site.

Corrections to the current site are entered into the LGC by the commander's Attitude Control Assembly (ACA), which is the three-axis, pistol-grip hand controller shown in Figure 1. When the PGNCS mode control switch is in the AUTO position and the LGC is in the Approach Phase Program, P64, the ACA will be disabled** as an attitude controller. Instead of controlling attitude, each ACA pitch deflection will cause the LGC to retarget the site so that its window elevation changes 0.5 degree. Each ACA roll deflection will cause the LM window azimuth reading of the current site to change 2 degrees. ACA yaw deflections will have no effect.

LPD control loops are summarized in Figure 3. The elevation and azimuth angles of the desired site, (EL_d, AZ_d) can be considered feedback quantities that describe the state of the desired site in window coordinates. The elevation of the current site, EL_c, must be voice-relayed to the commander by the LM pilot, since the commander cannot simultaneously view the DSKY and the desired site. Although no sampling element is explicitly shown in Figure 3, the commander will not track the desired site continuously but, instead, will input corrections to the desired site (N_e, N_a discretes) and wait several computation cycles to see if the desired site and the current site converge. The commander will also be refining the location of the desired site as viewing conditions improve during the Approach Phase.

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*This is actually the time-to-go to the Hover condition. Currently, the hover point is at an altitude of 150 feet above the landing site, with zero horizontal velocity, and -3 fps vertical velocity. (Reference 1)

**Both the commander's and the LM pilot's ACA are disabled.

LPD Attitude and Trajectory Response

The LM attitude and trajectory response for an example LPD redesignation is shown in Figures 4 and 5. (Data is from Reference 2.) The example redesignation given here is for a large redesignation outside of the current capability - 12,000 feet downrange and 5000 feet crossrange - but will validly illustrate several features of the LPD response. The transition to Hover is not shown in the attitude plots.

The attitude response of Figure 4 can be summarized as a roll transient, a yaw or heading change, and a pitch-down, pitch-up superimposed on the nominal slow pitch-down. The roll and yaw changes are of opposite sign, as will always be the case, for redesignation either left or right of the original target point. If a redesignation left of the target point is commanded, the response will be a positive yaw to zero the window azimuth of the new site, and a negative roll to tilt the thrust vector and redirect the velocity vector toward the new target. Redesignation to the right of the original target will result in a negative yaw response and a positive roll response. Redesignation right of the original target is limited by the commander's view from the LM left window. (See Figure 1)

At the approach to Hover, the roll attitude shown in Figure 4 would place the local horizontal level in the window, and the heading would be such that the site would not be directly forward through the LM windows. Of course, with manual takeover at approach to Hover, the yaw attitude can be changed to permit either a larger or smaller angle between the viewing vector and the LM XZ plane. (LM vehicle coordinates are shown in Figure 2.)

The dotted line shown on the pitch response plot in Figure 4 illustrates the approximate pitch behavior for an un-redesignated Approach Phase. Compared to this nominal pitch response, the redesignated response is a pitch-down followed by a slow pitch-up and pitch-down sequence, which approaches the nominal pitch profile as the hover point is approached. The initial pitch-down results in a forward velocity higher than nominal, and permits the target to be moved downrange of the original target.

If the redesignation illustrated in Figure 4 had been uprange - that is, short of the original target - then the initial pitch response would have been a pitch-up relative to the nominal pitch-up profile. Pitch-up will increase the window elevation angle, and might place the site below the bottom of the commander's window. The result would be loss of closed-loop LPD control. For this reason, redesignation capability short of the original target is limited, as will be discussed further in subsequent sections.

The roll, pitch, and yaw curves shown in Figure 4 become more oscillatory as the hover point is approached. These oscillations reflect the computer simulation technique of Reference 2, and are not necessarily representative of actual pilot control. With manual takeover on approach to Hover, the roll curve would probably be smoother.

The LPD trajectory response for the example redesignation is shown in Figure 5. The trajectory turns toward the new target with a large radius of curvature. This curvature should be of only small significance for manual takeover. Takeover may occur as early as 500 feet altitude and 1200 feet uprange of the site. (Reference 4) From this position, the crew need not fly a curved trajectory, with the LM slightly banked, but can fly a series of straight trajectories, with a combination of yaw and pitch maneuvers and small roll corrections. Simulations on the LLRF have shown a minimum of roll activity for an essentially straight trajectory. (Reference 3)

Redesignation Capability

The LPD redesignation capability is limited primarily by four factors: (1) the characteristic velocity budgeted for redesignation, (2) the viewing envelope of the commander's window, (3) the required DPS (Descent Propulsion System) throttle setting, and (4) the Landing Radar limitation on vehicle roll. These limitations are depicted in Figure 6 in a crossrange/downrange coordinate system centered at the nominal landing point. (Data is from References 5 and 6.)

The LPD capability depicted in Figure 6 should be considered an upper bound on the actual redesignation capability. The plot shown is for redesignation at an altitude of 5000 feet and a horizontal range 17,000 feet short of the original target. Simulations have shown that the crew is not likely to redesignate above this altitude. (Reference 7)

The current delta-V allotment for LPD redesignation is 60 fps (Reference 8). The corresponding redesignation locus is labeled "Current 60 fps" in Figure 6, and was approximated using the data of Reference 6. This curve indicates that at 5000 feet altitude the 60 fps allotment will permit crossrange redesignations of up to 3400 feet and downrange redesignations of up to 1600 feet.

Redesignation uprange (short) of the original target will decrease the required delta-V, and can be represented by curves inside of the "zero fps" curve on Figure 6. The uprange redesignation capability is limited by loss of visibility accompanying the required pitch-up. The dotted curve labeled "pitch-up limitation" is the boundary for uprange redesignation. (Both the "zero fps" and "pitch-up limitation" curves were taken from Reference 5, and are somewhat optimistic for the current descent trajectory.)

Redesignation to the right of the original target is very limited due to the commander's restricted viewing envelope. Figure 7 shows the structural viewing restrictions for the LM left hand window. When these viewing restrictions are transformed to Figure 6, redesignation is excluded outside of the area enclosed by the lines labeled "window limitation". With his eye at the design-eye position, as it must be to align the inner and outer LPD scales, the commander simply cannot see points on the lunar surface outside the indicated area.

The third major redesignation constraint is imposed by limits on the DPS throttle setting. Because DPS operation between 60% and 92.5% of full throttle is undesirable, the throttle will jump to 92.5% if the thrust commanded by the LGC is greater than 60%. A jump to full throttle might cause the LGC to command an attitude transient that would be undesirable during the Approach Phase. Therefore, it is assumed that redesignation should not be permitted if the resulting throttle command will exceed 60%. All target points lying outside the curve labeled "60% throttle limit" must be excluded from the redesignation envelope.

The fourth major consideration that will limit LPD redesignation capability is the effect of vehicle roll on Landing Radar operation. The curve labeled "current 30° roll locus" in Figure 6 is an approximation to the locus of redesignated target points that would require a maximum roll angle of 30 degrees. (Data is from References 5 and 6.) For some landing sites, the lunar terrain characteristics might be such that the Landing Radar would lose lock or cause unacceptable update errors, for roll angles of 30° or larger. Large roll angles would also be uncomfortable for the crew and, although the roll angle would decrease toward the hover point (Figure 4), there would be an effect on the manual takeover initial conditions. Lacking further data, 30° roll was chosen as a limit for LPD redesignation.

The result of the four major LPD constraints is that the redesignated target point must be chosen to lie within the area approximated by the shaded portion of Figure 6. This area defines the redesignation task of the LM commander - to choose a desired landing point that does not violate the stated constraints. The next section will discuss piloting considerations involved in the selection and tracking of a desired landing site. The intent of the discussion will be to develop a set of conditions for flight testing the LPD.

SECTION 2: LPD PILOTING ANALYSIS

Use of the LPD will add several tasks to the crew's overall piloting responsibility during powered descent. It is therefore important to determine the nature of these LPD tasks and their compatibility with other crew activities. This section will consider three main areas of crew task impact: (1) realtime selection of the desired landing point, (2) tracking the desired landing point, and (3) initiation of manual takeover.

Landing Point Selection Criteria

The crew will redesignate to a new landing point for one or both of two reasons: to avoid undesirable terrain, and/or to land near an object of scientific interest. For either purpose, redesignation must be accomplished within the constraints that were discussed in the previous section.

The redesignation capability at 5000 feet altitude was depicted in Figure 6. This capability can be transformed into angular changes in the window elevation and azimuth, as shown in Figure 8. The 1600 feet maximum downrange redesignation capability is equivalent to a window elevation change of 1.3 degrees. The 3400 feet maximum crossrange redesignation capability is equivalent to a window azimuth change of 11.3 degrees. As shown in Figure 9, the total allowable redesignation area at 5000 feet altitude is a very small portion of the commander's overall field of view. The 1.3 degree downrange limitation is probably close to the combined LPD instrument error and reading error. For this reason, redesignation for flight test purposes, at 5000 feet, should be largely in the crossrange direction. Three azimuth pulses (6.0 degrees), or 2000 ft. crossrange (6.7°) at 5000 feet altitude, is an upper limit on the extent of a flight test over smooth, or at least homogeneous, terrain.

In deciding how many redesignation pulses are allowable, the crew will need a chart similar to that shown in Figure 10. For off-nominal conditions, a chart with total velocity as the independent variable might be better. It should be noted that the chart in Figure 10 is for one redesignation only. A chart for one redesignation plus corrections will evidently have to be constructed from ground simulation data.

Within the limitation of the LPD delta-V allotment, redesignation will be based on what the commander sees when he first views the landing site after High Gate. His initial task will be to identify the current DSKY site by watching it move up the LPD elevation scale. Once the current DSKY site is identified, the commander will determine if this is a debris-free site with acceptable terrain slopes. His answer will establish the basic purpose of any subsequent redesignation, as shown in Figure 11. If the current site is unacceptable, he will ask if there are any smooth sites in view that are within the LPD capability. If not, he will continue until viewing conditions improve; if close to manual takeover, he might decide to abort. In the case where the current DSKY site is acceptable, he will look for other smooth sites that are within LPD range and are closer to an object of scientific interest. If he does not find a better site, he will continue to the current target.

In constructing Figure 11, it was assumed that only one redesignation is possible. If a redesignation to avoid undesirable terrain were followed by a redesignation to land near a particular object, then a different logic would apply.

In summary, satisfaction of the very restrictive LPD constraints is the primary redesignation criterion. Within these constraints, there is probably enough capability for only one redesignation - either for terrain avoidance, or for selection of a more interesting site. Flight test of the LPD should be limited to a few initial redesignation pulses, and enough delta-V should be left for subsequent corrections further down the trajectory.

Landing Point Tracking

The LM commander will have to track both the current DSKY site and the desired site before entering any LPD commands. If the window coordinates of the desired and current sites are converging, he should not enter any commands until the relative motion is stable, or begins to diverge. If the desired and current sites are diverging, he will measure the angular separation on the window scale, convert it to the number of pulses, and enter these pulses with the hand controller.

Once a redesignation command has been entered, the commander must continue to visually track the desired site. If its coordinates differ from the current DSKY site, he must decide what additional corrections should be made and whether the required correction will keep the total LPD delta-V within the 60 fps allotment. If the desired site and the current site diverge after the initial redesignation is made, an overcorrection may have to be entered. If it is predicted pre-mission that overcorrection will be required, it will be desirable to include an overcorrection algorithm in the Site Location Updating Routine of the Approach Phase Guidance, P64.

Both the commander's visual tracking of the landing site and the LM pilot's readout of the DSKY must be accomplished along with a variety of other tasks during the powered descent Approach Phase. Figure 12 shows the general layout of LM displays which are of major importance during the powered descent Approach Phase. The commander will be stationed at the left hand window, and the LM pilot will be stationed principally at Panels 1 and 2. The LM pilot will read the DSKY registers at Panel 4 and voice-relay to the commander the LPD elevation angle of the current site displayed on the DSKY register. When he is not reading out the elevation of the current site, the LM pilot will be monitoring the other panels and receiving systems and trajectory status reports from the Mission Control Center (MCC).

Figure 13 contains a list of major piloting tasks for the Approach Phase. Beginning at High Gate, the Commander will either monitor the automatic pitchover, or perform the pitchover manually to assess the LM handling qualities. As the lunar surface comes into view, his eye adaption and visual orientation will begin. He will identify the current site, assess the crater density, crater sizes, and terrain slopes. After tracking the current site on the LPD scale, he will make a decision to redesignate or to continue. When the LM approaches 1,000 feet altitude, the commander will plan his final approach trajectory and prepare for manual takeover.

Meanwhile, the LM pilot will be monitoring the onboard systems and receiving trajectory and systems reports from MCC. The LM pilot will monitor the Landing Radar antenna position change and the DPS throttle-down after High Gate. He will continue to scan Panel 1 for DPS propellant temperatures, pressures and remaining usables. He will also monitor the Landing Radar and PGNCS altitude and altitude rate on the tape meters and DSKY, respectively. When the forward and lateral velocities are below 200 fps, he will monitor them on the X-pointers. If there is an LPD redesignation, he will note the attitude response on the attitude indicator on either Panel 1 or 2.

With these and other tasks, the LM Pilot will not be able to continuously readout the DSKY display of LPD current site elevation. Figure 14 shows the LPD elevation angle time history for the current nominal descent trajectory. With the present LM pilot task loading, it is probable that the LM pilot will be able to sample this curve every 5 seconds, in the best case. This sampling rate is equivalent to an LPD elevation angle change of about 2 degrees per readout, and should be compatible with the commander's visual tracking rate. If the LM pilot is too busy to monitor the DSKY, the commander may have to extrapolate the last readout over 10 or 15 seconds.

There are several problems with the LPD display scaling. The time to go to hover (TGO), displayed on the left of the R1 DSKY register (Figure 1), can only be displayed to a magnitude of 99 seconds (because of the two digit limit), although the visibility phase is nominally 155 seconds long. The crew will have to ignore the TGO display for the first 56 seconds of the Approach Phase. Second, if one pitch redesignation pulse is entered, the window elevation of the current site will change 0.5 degrees. However, the DSKY elevation angle display might not change in response to the pitch redesignation, since the display is only to the nearest whole degree. Third, the commander will find it difficult to judge the correct number of 0.5 degree pitch pulses, since the LPD window scale is graduated in 2 degree increments. (1.3 degrees is the forward redesignation limit at 5000 feet altitude.) Probably none of these scaling problems is serious enough to prevent proper use of the LPD. However, these scaling differences certainly will add to the difficulty of the uprange/downrange redesignation task.

In summary, tracking the current landing site cannot be a continuous activity during the Approach Phase. The LM pilot will probably be able to readout the DSKY at 5 second intervals when he is not too busy. If he has to check the LM side panel instruments or converse with MCC, the sampling interval could be 10 or 15 seconds. Although the unredesignated elevation angle time variation is roughly linear over the first half of the Approach Phase, a large readout interval could cause an error in extrapolating the motion of the current site on the window scale.

Manual Takeover Conditions

Redesignation with the LPD will introduce an attitude and trajectory change similar to that shown in Figures 4 and 5. In general, the LPD attitude response will require manual takeover while the LM is automatically flying a slightly banked, slightly curving trajectory toward the redesignated site. There will probably be a pilot preference to zero the roll angle and fly a series of straight trajectories using pitch and yaw control. (Reference 3) It is difficult to state whether this will increase or decrease the delta-V required for a successful landing. Ground simulations should be run in order to determine the degree of coupling between the LPD attitude and trajectory response and the pilot response at initiation of manual takeover.

SECTION 3: FLIGHT TEST DEFINITION

The LPD constraints and piloting considerations discussed in Sections 1 and 2 indicate that only a very limited type of LPD flight test should be attempted on Mission H-1.

A definition of such a flight test is as follows. (A smooth, homogeneous terrain is assumed; that is, hazard avoidance using the LPD is not considered.)

A) Identify the current DSKY site and track it to 5000 feet altitude.

B) At approach to 5000 feet, identify a site approximately 6 degrees to the left and 0.5 degrees back from the current site. Enter three roll-left pulses and one pitch-up pulse.

C) Monitor the roll, pitch, and yaw response.

D) Continue to track the desired site until manual takeover.

E) At manual takeover, set up an approach to the desired site.

The delta-V curves given in Figure 6 indicate that the extra propellant required by this test will be nearly zero. The roll response will be almost 30 degrees, and the effect on the Landing Radar performance can be predicted pre-mission. The effect of the LPD attitude response on the initial conditions at manual takeover will be one output of the flight test, but the crew should perform pre-mission simulations of banked takeovers to establish a comfortable control envelope.

SUMMARY

A flight test of the LPD can be attempted on Mission H-1, but a number of constraints will limit the extent of the test. The redesignation can be planned to minimize the additional propellant required. Many of the crew tasks related to flight test of the LPD are already required by the nominal powered descent monitoring procedures. The data presented here are preliminary and only the qualitative conclusions are strictly valid. Current data must be prepared, and additional simulations must be run.

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References

1) Bush, G. L., "Latest MSC LM Descent Trajectory", Memorandum for File, Bellcomm, Case 310, April 24, 1969.

2) Klumpp, A. R., "A Manually Retargeted Automatic Descent and Landing System for LEM", MIT/IL, R-539, March 1966.

3) Mallick, D. L., et. al., "Flight Results Obtained with a Non-Aerodynamic, Variable Stability, Flying Platform", NASA-TM-X-059039, 1967.

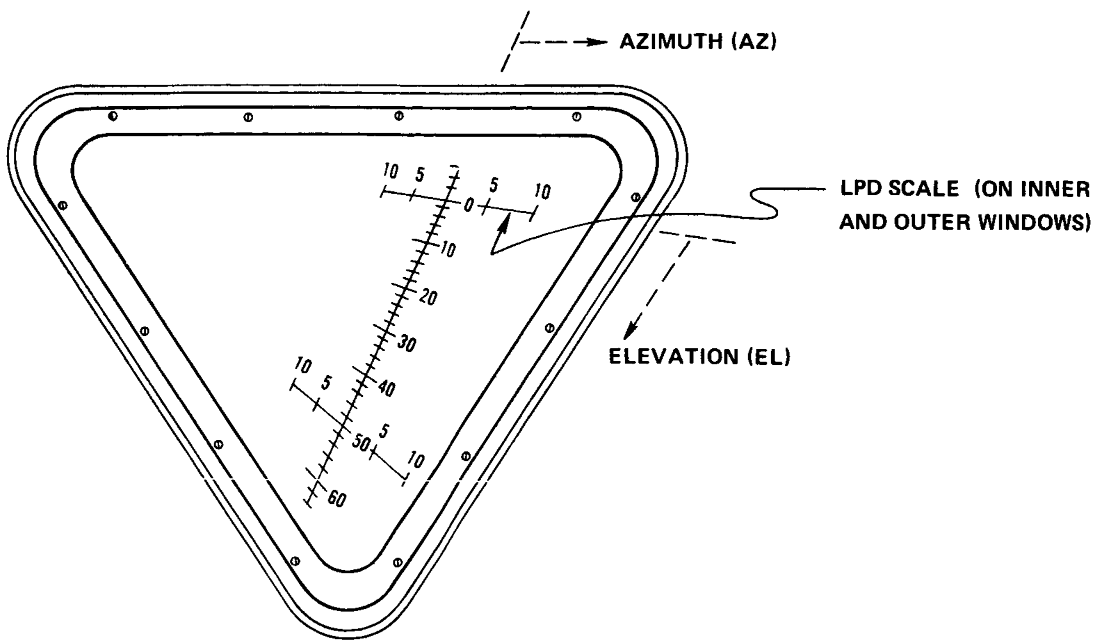
4) Nassiff, S. M. & Armstrong, N. A., "Apollo Flightcrew Training in Lunar Landing Simulations", AIAA Paper 68-254, March 25, 1968.

5) Montgomery, J. D. & Lefler, R. M., "LM Landing Point Designator Procedures and Capability", MSC Internal Note 67-EG-24, August 1, 1967.

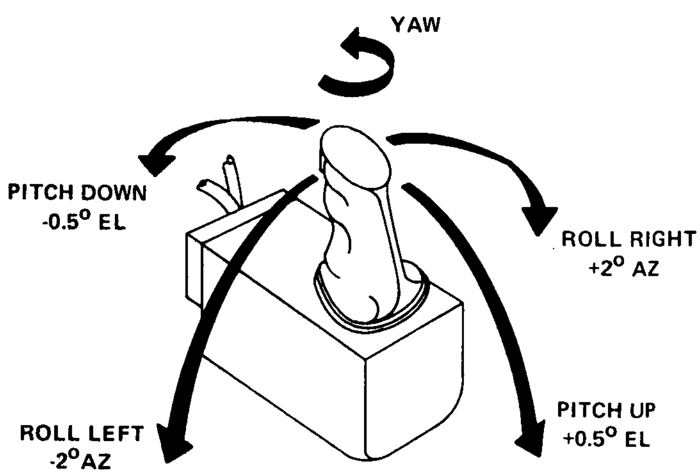
6) Hoekstra, T. B., "Presentation on LM Descent at 8:30 APO Staff Meetings of June 10, 12 and 16, 1969", Memorandum for File, Bellcomm, Case 310, June 23, 1969.

7) Hackler, C. T., et. al., "Lunar Module Pilot Control Considerations", NASA-TN-D-4131, February, 1968.

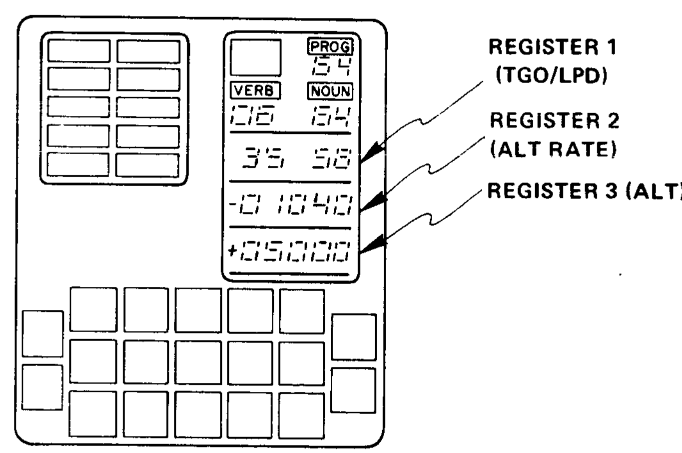
8) "Revision I to Apollo Spacecraft Weight and Mission Performance Definition (December 12, 1967)", MSC/ASPO May 15, 1969.



LEFT FRONT WINDOW



ATTITUDE CONTROLLER ASSEMBLY
(ACA)



DISPLAY & KEYBOARD
(DSKY)

FIGURE 1- LANDING POINT DESIGNATOR EQUIPMENT

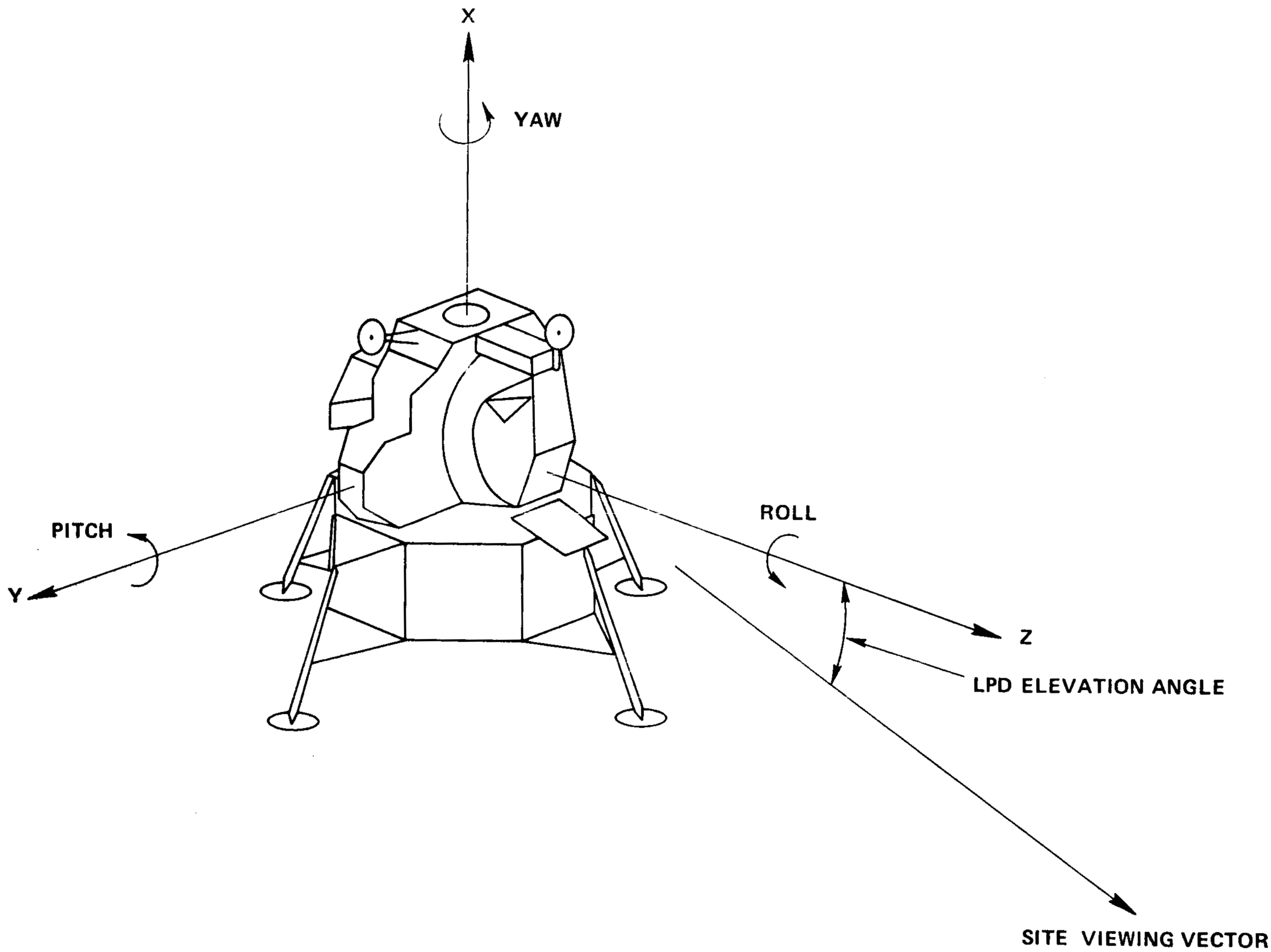
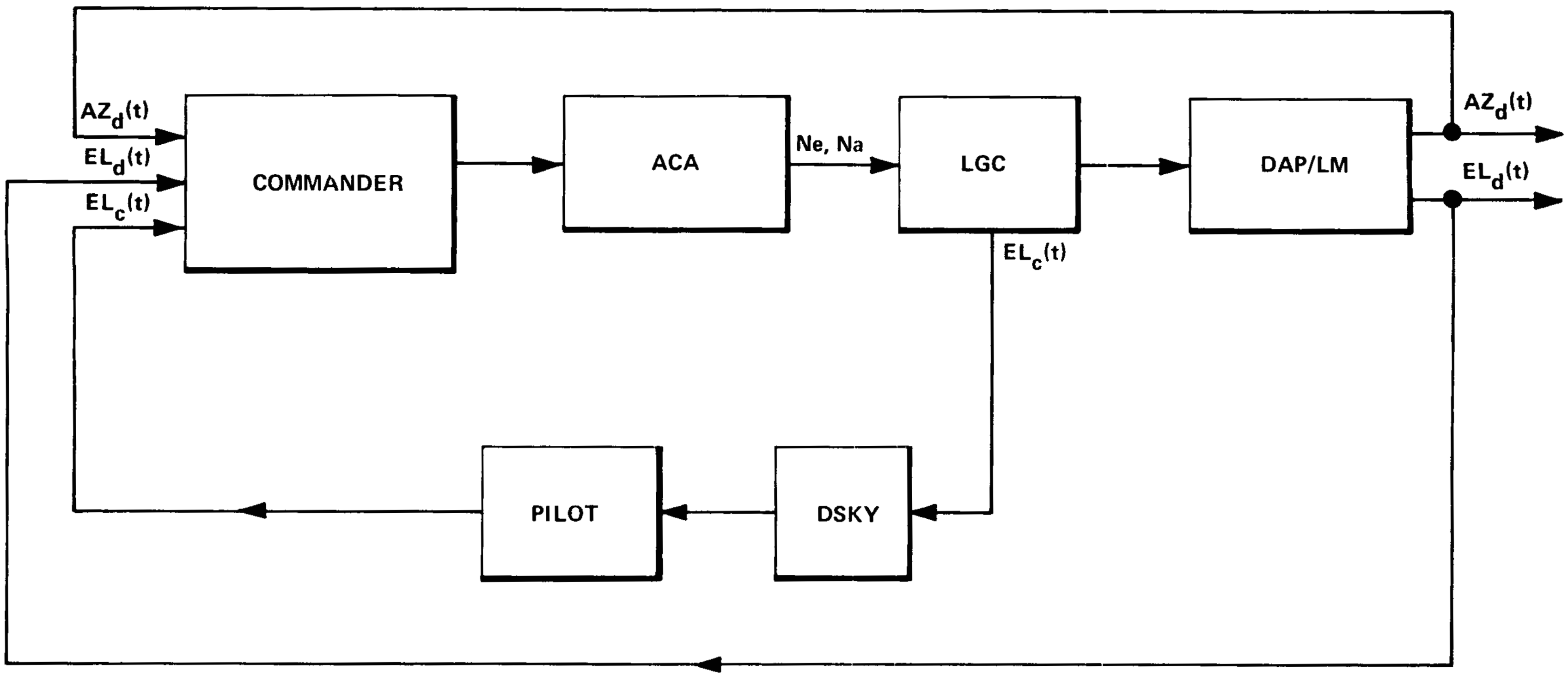


FIGURE 2 - LM ATTITUDE ANGLES



$EL_d(t)$, $AZ_d(t)$ = WINDOW COORDINATES OF DESIRED SITE
$EL_c(t)$ = WINDOW ELEVATION OF CURRENT SITE
Ne,Na = NUMBER OF DISCRETE ELEVATION, AZIMUTH COMMANDS

FIGURE 3- LPD CONTROL LOOPS

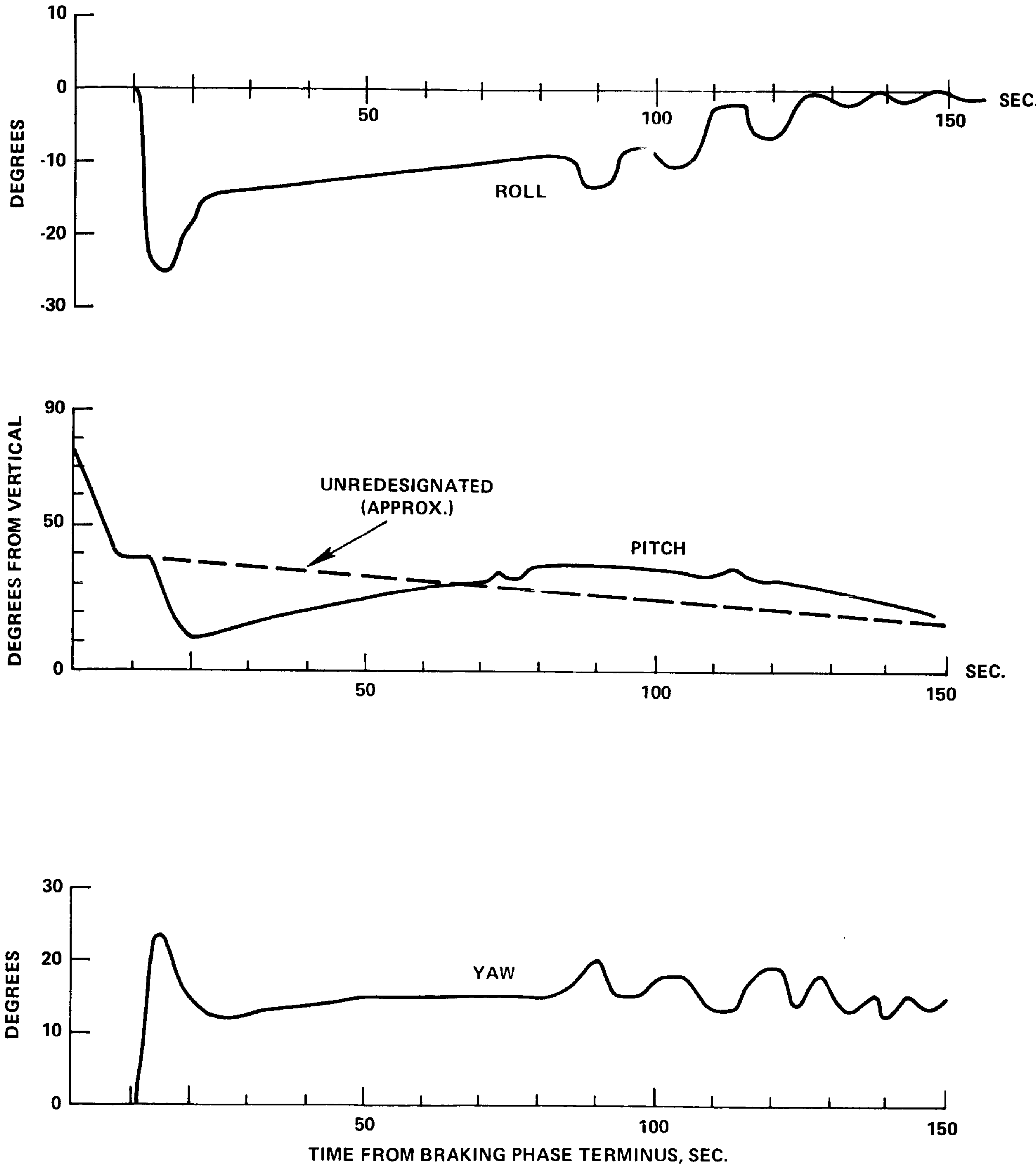


FIGURE 4- LPD ATTITUDE RESPONSE (FROM REF.2)

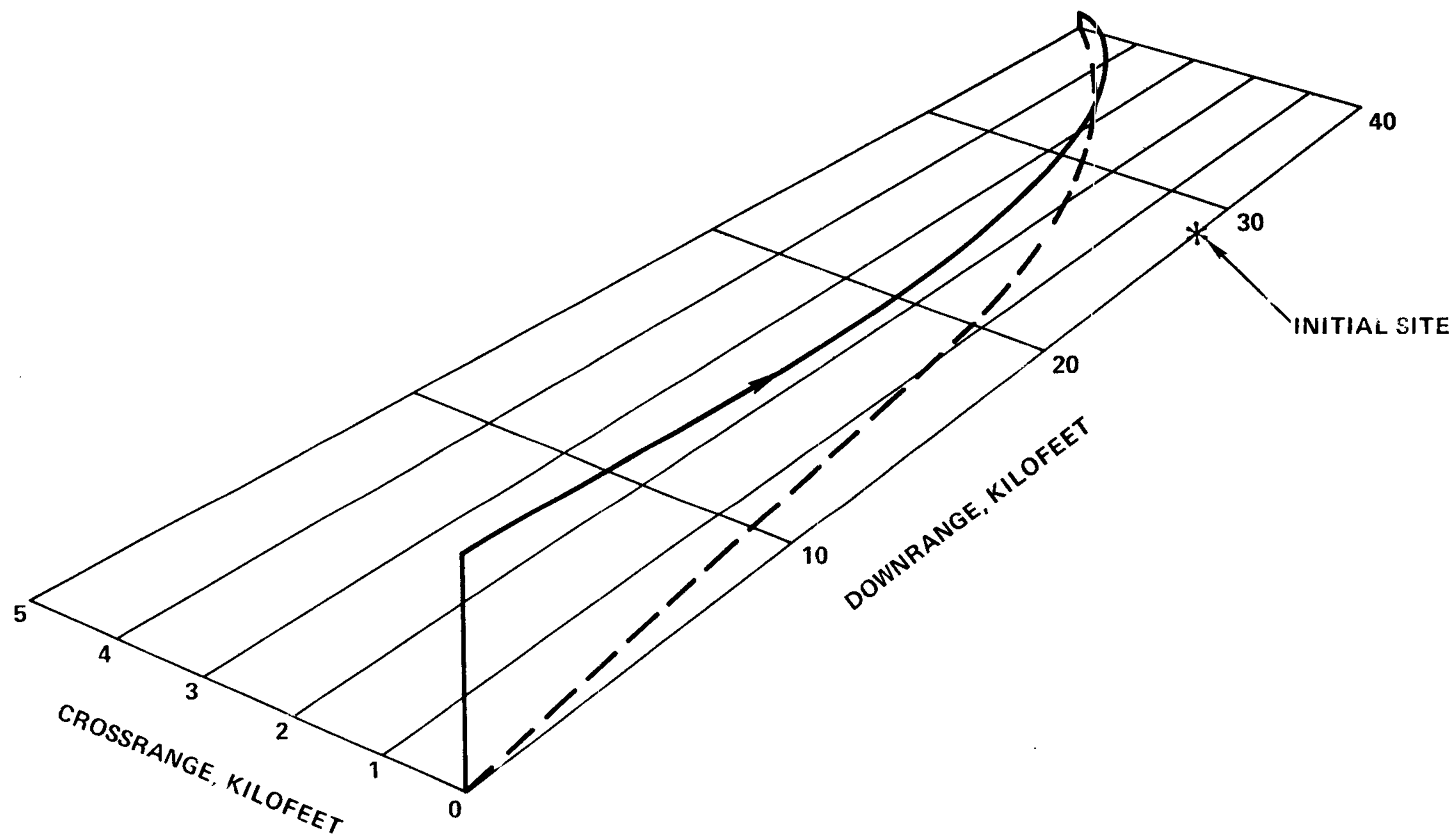


FIGURE 5- LPD TRAJECTORY RESPONSE (ADAPTED FROM REF. 2)

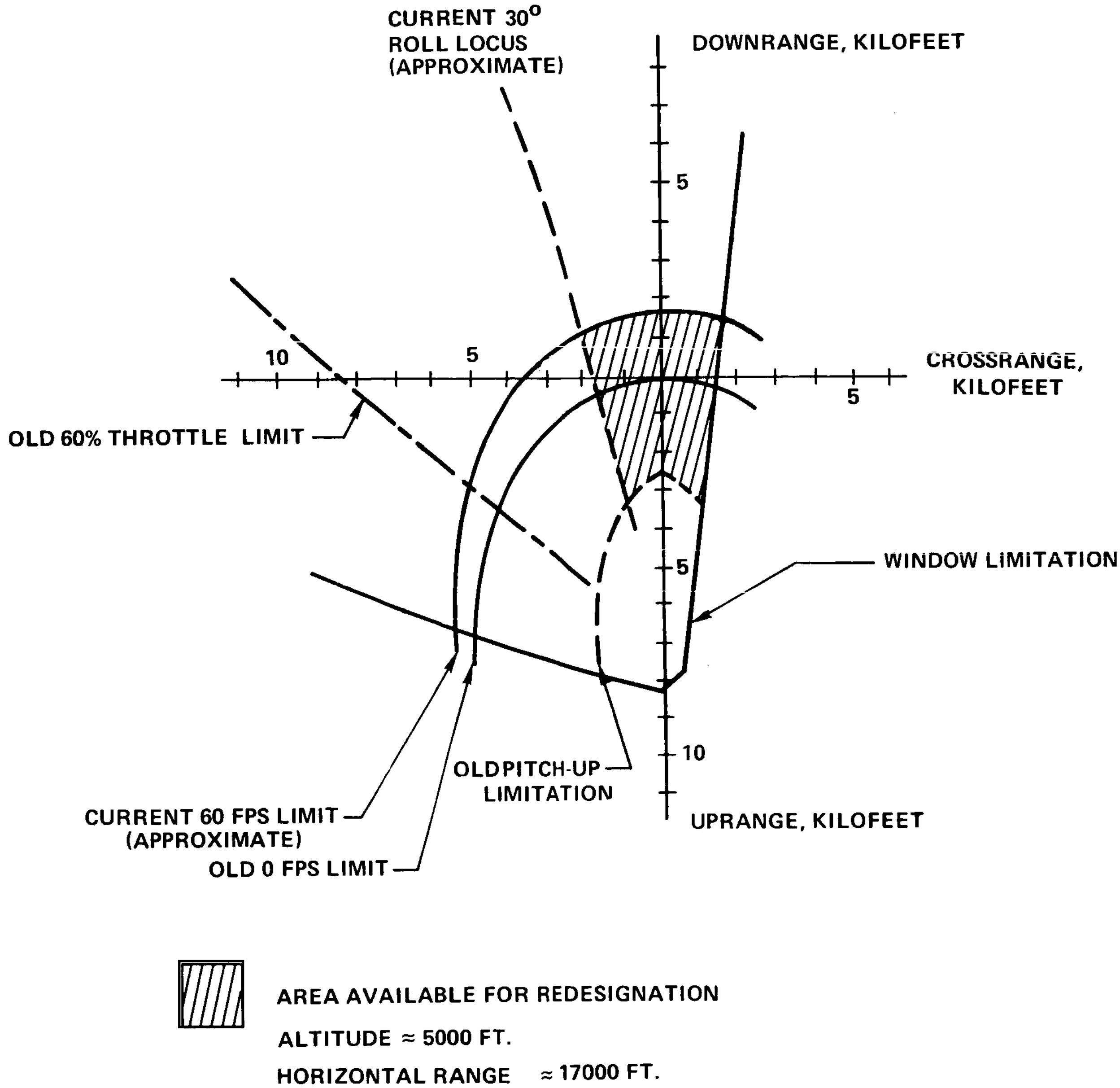


FIGURE 6 LPD REDESIGNATION CAPABILITY
(DATA OF REF 5& 8)

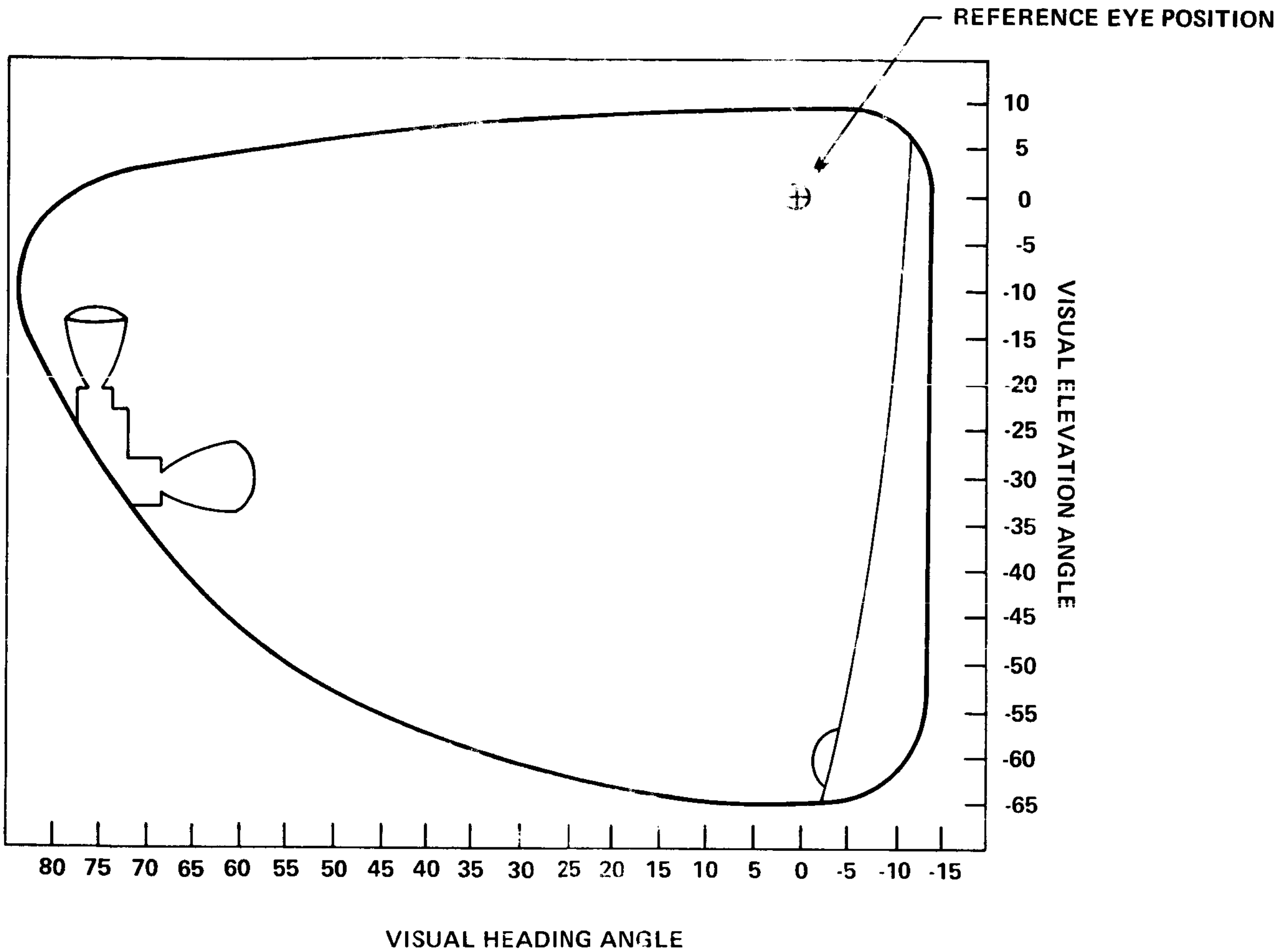
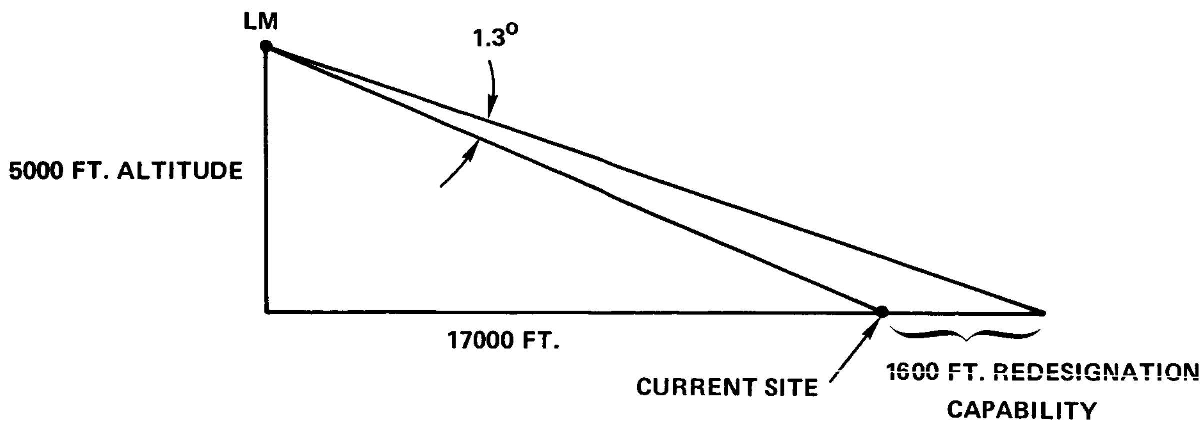
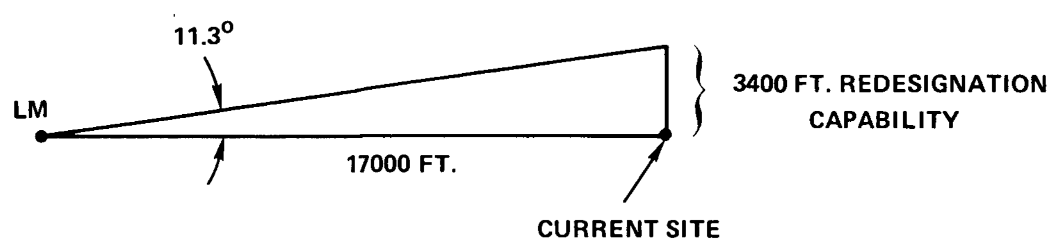


FIGURE 7 - COMMANDER'S VIEWING RESTRICTIONS



DOWNRANGE REDESIGNATION



CROSSRANGE REDESIGNATION

FIGURE 8- ANGULAR REDESIGNATION CAPABILITY AT 5000 FT. ALTITUDE

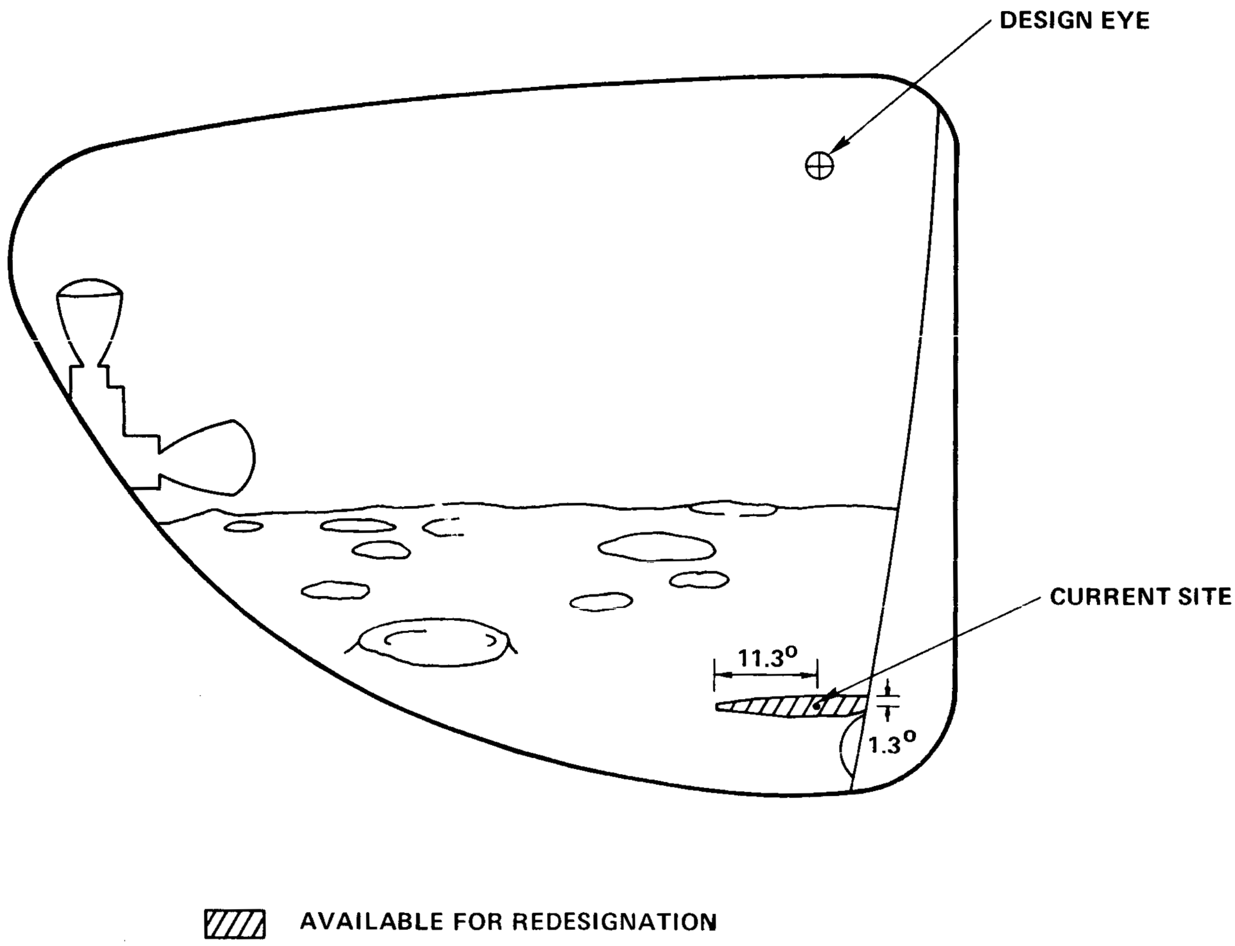
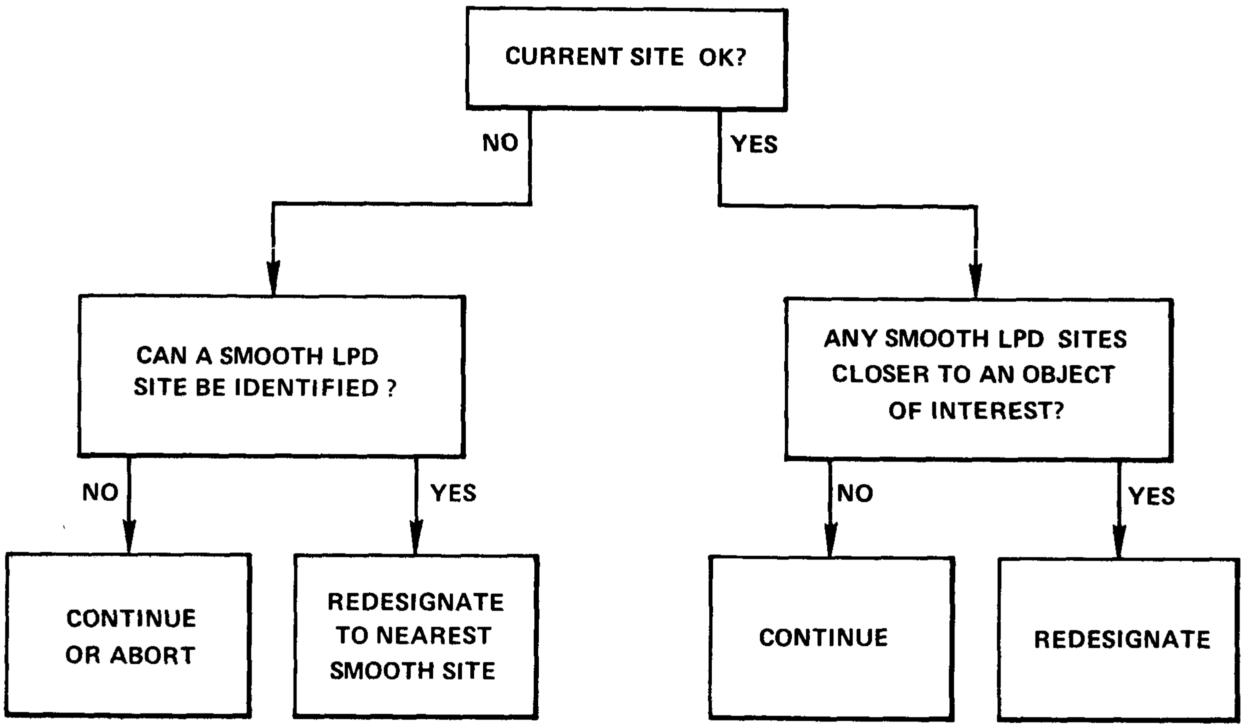


FIGURE 9 - APPROXIMATE REDESIGNATION AREA VIEW AT 5000 FT. ALTITUDE

	MAX. NO. PULSES	
ALTITUDE FT.	PITCH	ROLL
7000	+4, -4	+2, -4
6500		
6000		
5500		
5000	+4, -4	+2, -4
4500		
4000		
3500		
3000	+6, -4	+2, -5
2500		
2000		
1500		
1000	+12,-8	+2, -8

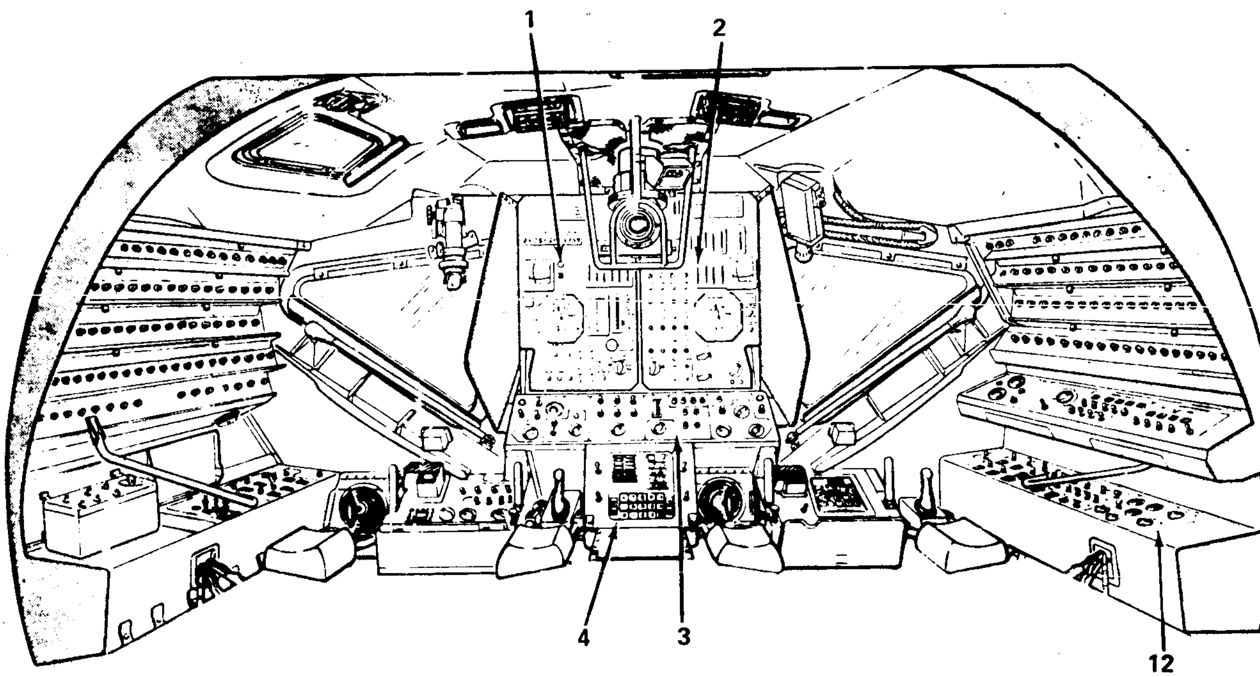
(30^{o} ROLL LIMIT)

FIGURE 10 - EXAMPLE ONBOARD CHART FOR LPD PULSE LIMITS
(ENTRIES FROM OLD DATA OF REF. 5)



(LPD SITE: A SITE WITHIN LPD CONSTRAINTS)

FIGURE 11 - REDESIGNATION LOGIC



LM CABIN

PANEL	DESCENT DISPLAYS
1	DPS STATUS, VEL, ALT, ALT RATE, ATTITUDE
2	ECS, RCS STATUS, ATTITUDE
3	LANDING RADAR
4	DSKY: TGO, EL, ALT RATE, ALT
12	COMMUNICATIONS

FIGURE 12 - LM DISPLAYS & CONTROLS

COMMANDER	LM PILOT
• MANUAL PITCHOVER TO ASSESS HANDLING QUALITIES OR MONITOR AUTOMATIC PITCHOVER	• MONITOR LANDING RADAR ANTENNA POSITION CHANGE
• EYE ADAPTATION	• MONITOR DPS THROTTLE DOWN
• READ MAPS, CHARTS, PHOTOS	• CALL OUT LANDING SITE ELEVATION
• IDENTIFY CURRENT SITE	• MONITOR ALT/ALT RATE
• ESTIMATE CRATER SIZES AND TERRAIN SLOPES	• MONITOR ECS, RCS
• VOICE DESCRIPTION OF SCENE	• RECEIVE MCC STATUS REPORTS
• TRACK CURRENT SITE	• MONITOR X- POINTER FOWARD AND LATERAL VELOCITIES
• REDESIGNATE	• MONITOR ATTITUDE INDICATOR
• PREPARE FOR MANUAL TAKEOVER	

FIGURE 13 - MAJOR APPROACH PHASE TASKS

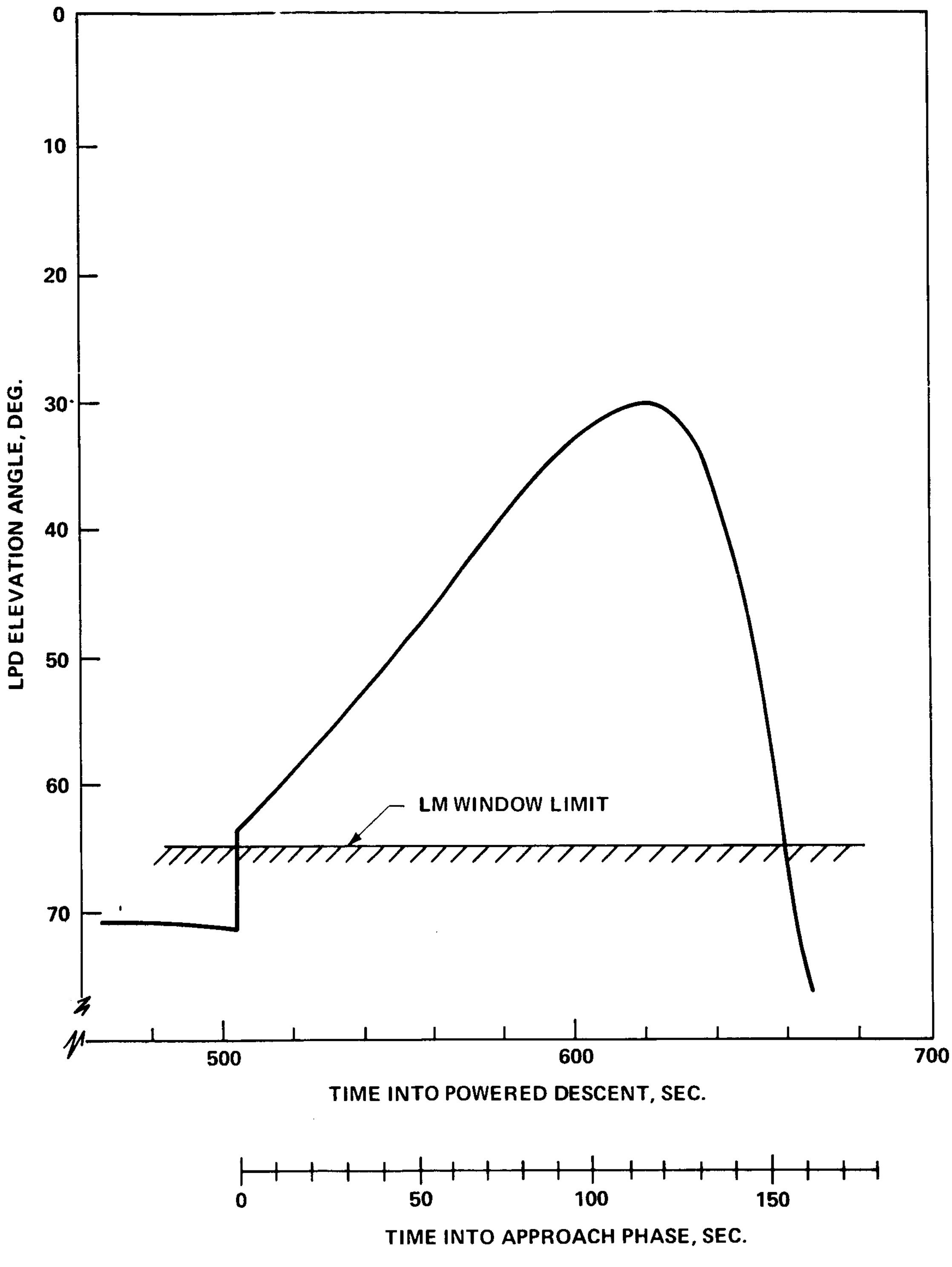


FIGURE 14- LPD ELEVATION ANGLE TIME HISTORY (REFERENCE 1)

BELLCOMM, INC.

Subject: Flight Test of the LM Landing Point Designator - Case 310

From: A. C. Merritt

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